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Discussion

Dr Charles D. Fraser *(Houston, Tex).* I really congratulate Dr Lee and colleagues for this important addition to our body of knowledge concerning the long-term effects of TOF repair on RV performance. This study really was beautifully presented, and I congratulate you on the concise nature of your slides and how clear and instructive they are.

From your original cohort of 251 patients undergoing TOF repair, some by classic RV outflow tract incisions, some by the transatrial/transpulmonary approach, 171 had complete MRI evaluations of RV performance at a mean of 15.5 years after the index correction. In your multivariable analysis for factors associated with late RV dilatation and dysfunction, you found male sex, interval from the original operation, and pulmonary regurgitant fraction to be independent predictors of an increased RV end-diastolic volume index. Of interest, residual RVOTO appears to be protective against RV dilatation and dysfunction.

My questions, first, the goal of the study was to provide additional insight into the treatment of these patients. Based on that premise, how has your thinking now evolved in terms of modifications you will make to the primary operation that you believe will confer long-term protection to RV function?

Dr Lee. Thank you for your excellent comments and question, Dr Fraser.

My institution is performing elective transatrial repair at 3 to 6 months of age for asymptomatic patients, and we prefer primary repair for the younger symptomatic infants. From ours, and other studies, I believe that leaving some degree of RVOTO will be protective against RV dilatation and dysfunction in the long term. However, the optimal degree of RVOTO remains to be determined, and our study could not answer this question. Moreover, it could be difficult to target the optimal degree of RVOTO intraoperatively, because we know that a tendency exists for a significant reduction in the transpulmonary gradient postoperatively. Additional studies are necessary to clarify this issue.

Dr Fraser. So, just to expand on that just a little bit, and I know there will be some other questions, but you would tend to leave a little more obstruction, be a little less liberal with your resection, and, where possible, would you preserve the moderator band?

Dr Lee. Yes, I think it is important to perform less resection of the infundibulum, to leave some degree of RVOTO. In our study, we found that the route of VSD closure was not an independent factor for RV dilatation and dysfunction. Last year, at this meeting, we presented rather disappointing results about limited RV incision in patients who underwent transannular repair. However, the findings of our study should not be interpreted as discouraging the use of the transatrial/transpulmonary approach for TOF repair. We still believe that transatrial/transpulmonary repair of TOF has some role for better long-term outcomes.

Dr Fraser. Just 2 quick more questions then. Tell us your institutional protocol for choosing patients for PVR now. What threshold do you use in terms of the interval from surgery, regurgitant fraction, end-diastolic volume, and so on?

Dr Lee. My institution is rather aggressive toward PVR. Definitely, we recommend PVR for patients with symptoms or exercise intolerance. For the asymptomatic patients—can I go back—this is our recent report about PVR in our center. In this study, the median age at PVR was about 17 years, and we found that PVR should be considered before the RV EDVI exceeded 163 mL/m^2 or the RV end-systolic volume index exceeded 80 mL/m^2 to achieve postoperative normalization of the RV volumes and function. It is difficult to know whether achieving normal RV volumes and function after PVR is absolutely necessary for better long-term outcomes; however, until proved otherwise, we have trying to not exceed these cutoff values for the asymptomatic patients.

However, in practice, it has not always been possible to do this. Sometimes, our cardiologists perform echocardiography and find a severely dilated right ventricle, then they perform the MRI and find a severely, very severely dilated right ventricle, for example, an RV EDVI of 200 mL/m^2. For this patient, I think we would be operating too late.

Therefore, to incorporate these cutoff values into the clinical decision-making process, we should know the course of RV dilatation and dysfunction. Also, I think this can be done by performing serial MRI examinations, and this is an important issue for future studies to assist in refining the optimal timing of PVR.

Dr Fraser. One last question. I cannot resist. So, as those of us who have been married as long as I have know, the male sex is disadvantaged. Why is that so in patients with TOF?

Dr Lee. Our result about the male sex is in accordance with the findings from some previous studies. For example, the Atlanta group reported that male sex was a significant risk factor for a shorter interval between pulmonary valve disruption and PVR. However, it is difficult to ascertain whether true sex-specific differences exist in the RV response to chronic volume overload, because previous studies have reported sex-specific differences in normal RV volumes and function. If our study result is simply a reflection of the sex-specific differences in normal RV volumes, I think we should apply sex-specific criteria for prescribing PVR. Female patients will experience relatively more severe RV dilatation and dysfunction if we use unisex criteria for PVR, and, certainly, this will be an area of future study.

Dr Hillel Laks *(Los Angeles, Calif).* A question and a comment. First of all, the sex difference could be related to the degree of physical activity in the first 12 years of life, or 14 or 15 or 18 years of life, and males might be much more active during this period than females, but that is just speculation.

The second point is, I think, it is very important when we talk about MRIs of the right ventricle to differentiate between 2 portions of the right ventricle. The right ventricle has a contractile ejecting lower chamber and an outflow tract. It is not infrequent, and we have seen this in our own institution, where a patient can have a patch that was made transannular with a huge RV aneurysm and pulmonary artery aneurysm. However, the actual contracting chamber below it will not be dilated and will be working extremely well. The MRI personnel who perform these studies include the infundibulum and this aneurysm as part of their volume and in calculating the EF. So, depending on the technique used, you can have an outsized volume and a lower EF in a patient whose actual contractile chamber is still doing extremely well. We try to differentiate that. If it is just the aneurysm issue, because a nontreated pericardial patch was used and was made too large, that does not mean the right ventricle is failing. I assume that in your institution, with close to 80% TAPs, that the surgeons were extremely careful not to make very large incisions down into the right ventricle and not to use a patch that would expand and cause that to explain your excellent results and the lack of differentiation.

So, I think that until the time comes when we start asking our radiologists and cardiologists who do these calculations to separate these 2 issues, we will not have a good idea on what is actually happening to RV function, in contrast to global issues that are frequently surgeon-related and technique-related.

Dr Lee. Thank you for your comments. I agree with your opinion about the functioning RV trabecular portion and that measuring the RV trabecular portion's volume and function is important. However, I heard from my radiologist that it was not always clear to divide the right ventricle into the trabecular and infundibular portion. That is a problem.

Dr Christoper A. Caldarone *(Toronto, Ontario, Canada).* Could I just ask, in your multivariable analysis, the RV EF appeared to be associated with some improvement in the face of RVOTO and the hazard ratio was 5.4. What are the units in that hazard ratio? For example, is it expressed in some percentage of change in the EF normalized by some change in the pressure gradient?

Dr Lee. RVOTO was entered into the analysis as yes or no, the presence or absence of RVOTO.

Dr Caldarone. Oh, I see. So, this is a binary association?

Dr Lee. Yes.

Dr Caldarone. So that would be an interesting relationship to study. Rather than creating discrete intervals in the RV outflow tract gradient, the use of this variable as a continuous variable would be informative.

The other point to consider is an interaction term might be present between RVOTO and the regurgitant fraction. A greater regurgitant fraction could be associated with a greater gradient. However, perhaps a gradient is protective, exactly as you said. But, I think those 2 terms really need to be examined carefully for a potential interaction in confounding your analysis.

Dr Lee. We did not examine the relationship between RVOTO and regurgitant fraction, so I cannot answer that question.